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# EFFECT OF PROCESS PARAMETERS OF WEDM ON SURFACE ROUGHNESS AND MATERIAL REMOVAL RATE FOR ALLOY MATERIAL (AL6101-T6) USING TAGUCHI METHOD

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## ABSTRACT

WEDM (Wire Electric Discharge Machining) process is used to cut conductive metals of any hardness. The process is specialized in cutting complex contours or fragile geometries that would be difficult to be produced using conventional machining process. The literature review has revealed that very less research work has been done in order to achieve optimal levels of process parameters for alloy material AL6101-T6 using zinc coated brass wire electrode. The objective of the present research work is to study the effect of different process parameters viz. pulse on time, pulse off time, servo voltage and wire feed rate on the response parameters viz. material removal rate, surface roughness using 0.25 mm diameter zinc coated brass wire. Taguchi design methodology has been chosen for design of experiment and L9 orthogonal array (OA) has been selected for present study.

**KEYWORDS :** WEDM, MRR (Material Removal Rate), SR(Surface Roughness), Taguchi Method, OA, S/N Ratio.

### 1. INTRODUCTION
Aluminium alloys have got many applications in different industries viz. automobile industries, Aeronautical industries, domestic use etc. but there is very less amount of research work on aluminium alloys using wire Electrical Discharge Machining (WEDM). So, in the present work, aluminium alloy AL6101-T6 is taken as work material & it is machined by WEDM. Emphasis is given to find the effect of process parameters of WEDM on Material Removal Rate (MRR) & Surface Roughness (SR). In 1969, the SWISS FIRM AGIE produced the world's first wire electric discharge machine, the process was fairly simple, not complicated and wire choices were limited to copper and brass only [1]. Wire Electric Discharge Machining (WEDM) has greatly improved in terms of accuracy, quality, productivity and precision, thus immensely helped the tooling and manufacturing industry. WEDM operated in industry today are equipped with Computer Numerical Control (CNC) which helps in improving efficiency and accuracy [2]. WEDM is considered as a unique adoption of the conventional EDM process which uses a continuously moving wire as electrode. The degree of accuracy of work piece dimensions obtainable and the fine surface finishes make WEDM particularly valuable for applications involving manufacture of stamping dies, extrusion dies and prototype parts [3]. WEDM is a process which erodes and removes material by the electric sparks generated in the small gap between the wire electrode and the work piece at a pulsating direct current supply of 20 to 30 kHz. De-ionized water is used as the dielectric fluid which stabilizes the sparks and flushes out the eroded metal. As there is no direct contact between the work piece and the wire, the mechanical stresses are absent during machining [4]. Material removal rate (MRR) and surface roughness (SR) of the machined surface by wire EDM will depend on different machining parameters such as pulse on time, pulse off time, servo voltage and wire feed rate.

### 2. EXPERIMENTATION AND METHODOLOGY
#### 2.1. Experimentation
The experiments were carried out on the ELEKTRA SPRINTCUT 734 WEDM machine of Electronica Machine Tools Ltd. installed at CNC Lab in Department of Mechanical Engineering, YMCAUST, Faridabad, Haryana, India.

**Table 1. WEDM machine tool specifications:**

| Features | Values |
|---|---|
| Design | Fixed column, moving table |
| Table size | 440 x 650 mm |
| Max. work piece height | 200 mm |
| Max. work piece | 500 kg |
| weight | |
| Table size | 300, 400 mm |
| Auxiliary table traverse (u, v) | 80, 80 mm |
| Wire electrode diameter | 0.25 mm (Standard) |
| Generator | ELPULS-40 A DLX |
| Controlled axes | X Y, U, V simultaneous / Independent |
| Interpolation | Linear & Circular |
| Least input increment | 0.0001mm |
| Least command input (X, Y, u, v) | 0.0005mm |
| Input Power supply | 3 phase, AC 415 V, 50 Hz |
| Connected load | 10 KVA |
| Average power consumption | 6 to 7 KVA |

The author purchased the flat sheets of alloy material AL6101-T6 of sizes respectively. Nine work pieces of alloy material AL6101-T6 of approximate equal sizes had cut from the purchased sheets on the Mechanical Shear off Machine. The thickness of each work piece was 6 mm.

In WEDM the electrode is a continuously moving wire which is feed at a constant desired rate. Here the wire used was Zinc coated brass wire of diameter 0.25 mm. The properties of the wire as given by the manufacturer are listed in the Table 2.

Four parameters viz. pulse off time, pulse on time, servo voltage and wire feed rate were selected as process parameters. Three levels for each factor had been selected during experimental work. Selected levels for the above stated four input parameters and the fixed parameters are shown in Table 3.

**Table 2. Wire Composition**

| Wire type | Diameter (mm) | Core Composition | Coating Composition | Tensile Strength (kgf/m$^2$) | Color |
|---|---|---|---|---|---|
| JET CUT ATS | 0.25 | CuZn37 | Zinc | 60 – 65 | Silver Grey |

***Source:*** *Manufacturer manual*

**Table 3. Process Parameters and their Levels**

| Input Parameters | Symbol | Units | levels | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| Pulse on Time | TON | µs | 100 | 115 | 130 |
| Pulse off Time | TOFF | µs | 30 | 40 | 50 |
| Servo Voltage | SV | Volt | 50 | 60 | 70 |
| Wire Feed Rate | WF | m/min | 1 | 2 | 3 |

The procedure followed during machining operation on WEDM machine tool included following steps viz.

a) The wire was made vertical with the help of verticality block

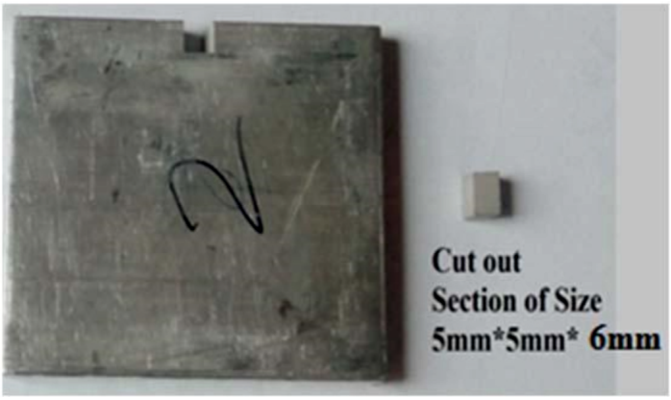
b) The work piece was mounted and clamped on the work table

c) A reference point on the work piece was set for setting work co-ordinate system (WCS). The programming was done with the reference to the WCS. The reference point was defined by the ground edges of the work piece

d) A gap of 8 mm between upper and lower nozzles cum wire guides was maintained during all the experimental trials

e) The program was made for cutting operation on the work piece and a U shaped cut of size 5 mm × 5 mm was obtained on each of the nine work pieces of Aluminium.

The Aluminium work piece after machining is shown in Fig. below




## 2.2. Methodology

Robust design of an experiment is very necessary to reach at accurate result. The author has used "*The Taguchi Method*" as *design of experiment (DOE)* technique. The methodology involves identification of controllable and uncontrollable parameters and the establishment of a series of experiments to find out the optimum combination of the parameters which has greatest influence on the performance and the least variation from the target of the design [7]. *Orthogonal array (OA)* plays a critical part in achieving the high efficiency of the Taguchi method. Taguchi's orthogonal arrays are experimental designs that usually require only a fraction of the full factorial combinations [7]. **$L_9$** OA for four parameters with three levels of each was used for Taguchi's approach to DOE

Taguchi DOE, $L_9$ OA, Signal to Noise (S/N) ratios calculations for response parameters, S/N ratio main effect plots were performed on MINITAB15 software..

**Table 4. $L_9$ Orthogonal Array**

| Experiment No. | Input Parameters | | | |
|---|---|---|---|---|
| | TON | TOFF | SV | WF |
| 1 | 100 | 30 | 50 | 1 |
| 2 | 100 | 40 | 60 | 2 |
| 3 | 100 | 50 | 70 | 3 |
| 4 | 115 | 30 | 60 | 3 |
| 5 | 115 | 40 | 70 | 1 |
| 6 | 115 | 50 | 50 | 2 |
| 7 | 130 | 30 | 70 | 2 |
| 8 | 130 | 40 | 50 | 3 |
| 9 | 130 | 50 | 60 | 1 |

The S/N ratio depends on the quality characteristics of the process to be optimized. In the present work three response parameters were chosen viz. material removal rate (MRR) and surface roughness (SR).The quality characteristics of these responses are shown below:

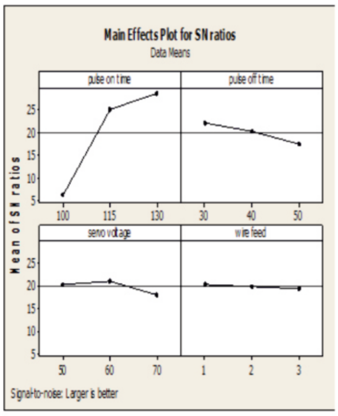
**Quality characteristics of response parameters:**

| Response Name | Response Type |
|---|---|
| MRR | Larger The Better |
| SR | Smaller The Better |

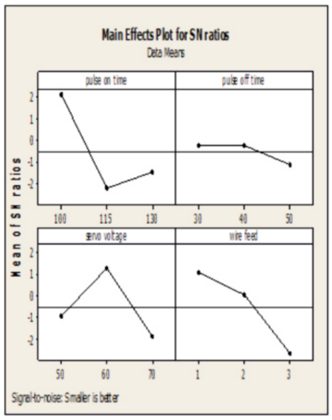
## 3. RESULTS AND DISCUSSIONS

### 3.1. Results for MRR and SR

The S/N ratios had been calculated to identify the major contributing factors towards MRR variation. The main effects plots for S/N Ratios for MRR gives the graphical variation of material removal rate with respect to input parameters viz. pulse on time, pulse off time, servo voltage and wire feed rate. The S/N ratios, main effects plots, response table for S/N ratios for MRR.




**effect of process parameters on MRR for S/N ratio**




**effect of process parameters on S/N ratio for SR**

## 4. CONCLUSIONS

As we increase the pulse on time the MRR increases at a rapid rate and then increases at a slower rate. As we increases the pulse off time, the MRR decreases. With increase in servo voltage firstly the MRR increases and then it decreases. With increase in wire feed rate the MRR decreases at a slower rate.

SR increases at a rapid rate with increase in pulse on time and later decreases at a slower rate . With increase in voltage, SR firstly decreases and then increases. SR increases with increase in wire feed. With increase in pulse off time SR remains constant upto a level and the it increases at a slower rate. Surface Roughness should be as minimum as possible, so, for this Signal-to-noise (S/N) ratio, smaller is better is considered.

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